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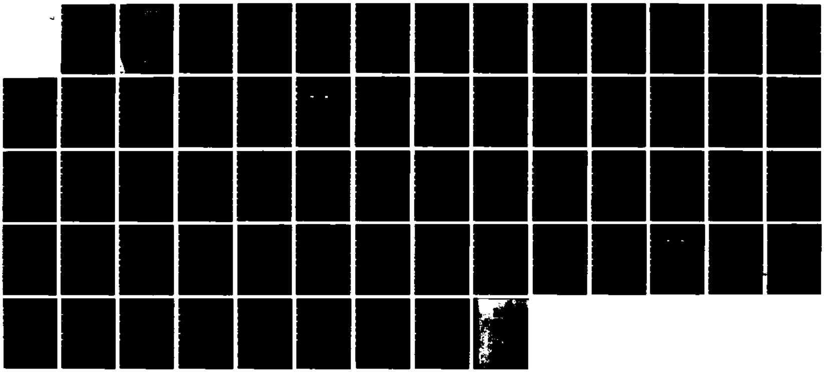

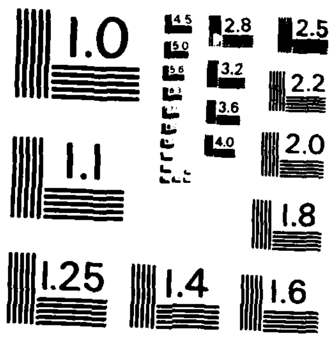

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Systems Engineering Service
Washington, D.C. 20591

Study of the FAA Program to Modernize Maintenance Operations

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16. Abstract

This report is an evaluation of the FAA's program to modernize the National Airspace System and reduce Maintenance and Operation Costs through replacement of present systems with state-of-the-art equipment, centralization of the maintenance work force and remote monitoring of equipment/facilities. A conclusion of the study was the FAA's Maintenance Program is a viable approach to meeting these goals. The AT&T study team made seven recommendations they believed would ensure improved productivity and reduced operating costs.

The objectives of the AT&T study were to evaluate the FAA's modernization program, and then, based on AT&T's experience in their modernization effort, make recommendations to improve the FAA's program. The recommendations can be generalized into three areas which are: (1) Separate the monitoring and control of facilities from the automation and centralization of operations, thereby enabling independent efforts in those areas. (2) Establish an overall program management plan, and (3) Establish a model for centralization of the work force in the automated environment.

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PREFACE

The study team would like to acknowledge Herm Tharrington, the RMMS Project Manager, for his assistance prior to the beginning of the study. We would like to thank Robert Beagley, Technical Officer, and Dave Zeller, Study Coordinator. Both Mr. Beagley and Mr. Zeller planned and arranged meetings, gathered documents necessary for our study, traveled with the team, and provided many helpful suggestions. Mr. Zeller also provided useful background information including a view of maintenance plans for the Alaska Region.

We would also like to acknowledge the help received from personnel in the Central Region, including Charles Douglas, Leon Hogan, and Phil Duffy. In addition, there were many other FAA people, who provided us with personal interviews, generously giving of their time, and sharing with us their knowledge and experience.

The Study Team

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LIST OF ABBREVIATIONS

AAC - Mike Monroney Aeronautical Center

AAD - Associate Administrator for Administration

AAP - Advanced Automation Program

AAT - Air Traffic Service

ACF - Area Control Facility

ADL - Associate Administrator for Development and Logistics

AES - Systems Engineering Service

AF - Airway Facility

AFSS - Automated Flight Service Station

APM - Program Engineering and Maintenance Service

ARSR - Air Route Surveillance Radar

ARTCC - Air Route Traffic Control Center

ASR - Airport Surveillance Radar

AT - Air Traffic

AT&T - American Telephone and Telegraph

ATC - Air Traffic Control

ATCBI - Air Traffic Control Beacon Interrogator

BOC - Bell Operating Company

CATLAS - Centralized Automatic Trouble Locating and Analysis System

CBI - Computer Based Instruction

COMMS - Central Office Maintenance Management System

EM - Electromechanical

EMPS - En Route Maintenance Processor Subsystem

FAA - Federal Aviation Administration

FMAC - Facility Maintenance and Administration Center

FMAS - Facility Maintenance and Administration System

FSAS - Flight Service Automation System

GNAS - General National Airspace System

GS - Glide Slope

ICD - Interface Control Document

ICSS - Integrated Communications Switching System

ILS - Instrument Landing System, Integrated Logistics Support

I/O - Input/Output

IRMP - Information Resources Management Plan

LRC - Limited Remote Control

LSSG - Lead Sector Steering Group

LSSSG - Lead Sector Software Steering Group

MALSR - Medium Intensity Approach Lighting System

MCC - Maintenance Control Center

MCS - Monitoring and Control Software

MLS - Microwave Landing System

MMS - Maintenance Management System

MOS - Maintenance Operations System

MPS - Maintenance Processor Subsystem

MPSG - Maintenance Philosophy Steering Group

NAS - National Airspace System

NFSS - National Field Support Sectors

OS - Operations System

PICS - Plug-In Inventory Control System

RCAG - Remote Center Air-Ground

RMC-F - Remote Monitor and Control - Flight Service Station

RML - Radar Microwave Link

RMM - Remote Maintenance Monitoring

RMMS - Remote Maintenance Monitoring System

RMMSG - Remote Maintenance Monitoring Steering Group

RMS - Remote Monitoring Subsystem

RMSC - Remote Monitoring Subsystem Concentrator

ROCs - Regional Operating Companies

SCANS - Software Change Administration and Notification System

SCC - Switching Control Center

SCCS - Switching Control Center System

SCOTS - Surveillance and Control of Transmission Systems

SE - Systems Engineering

SEI - Systems Engineering and Integration

SGV - Second Generation VORTAC

SI - Sensor Interface

SMMC - System Maintenance Monitoring Console

SMPS - Sector Maintenance Processor Subsystem

SPC - Stored Program Control

TAC - Technical Assistance Center

TACAN - Tactical Air Navigation

TASC - Telecommunications Alarm Surveillance and Control

TCAS - T-Carrier Administration System

TCN - Telecommunications Network

TIRKS - Trunks Integrated Record Keeping System

TNOP - Total Network Operations Plan

TOP - Task Oriented Practice

VOR - VHF Omnidirectional Range

VORTAC - Collocated VOR and TACAN

WC - Work Center

EXECUTIVE SUMMARY

INTRODUCTION

In the late 1970s, the Federal Aviation Administration (FAA) initiated an effort to modernize their maintenance operations. This became known as the 80's Maintenance Program. In early 1983, the FAA advertised their intention to have an independent review conducted of the 80's Maintenance Program by a company with relevant experience. AT&T submitted a proposal and was selected by the FAA because of experience gained since the late 1960s in modernizing the maintenance operations for the AT&T telecommunications network. A contract was negotiated for a study, which began on October 24, 1983. This report presents the results of that study.

In accordance with the Statement of Work, Contract Number DTFA01-84-C-0010 titled "A Study of the FAA Remote Maintenance Monitoring System (RMMS)," the study team examined the 80's Maintenance Program with the objective of recommending work that should be undertaken to enhance this Program. In particular, the study team examined the following three subject areas:

- Overall Program -- the 80's Maintenance Program, including the implementation plan, Program objectives, project responsibilities, and Program management.

- Work Centers -- the FAA maintenance work locations, including the Airway Facility (AF) Sectors and the sector structure, the Maintenance Control Center (MCC), repair facilities, National Field Support Sectors (NFSSs), and the people, their jobs, and their training.

- Systems and Maintained Equipment -- the Remote Maintenance Monitoring System (RMMS), including the maintenance capabilities associated with the National Airspace System (NAS) facilities, and the computer based capabilities required to centralize and automate the operations.

In the initial phase of the study, we reviewed each of these three subject areas by visits and meetings with FAA Headquarters and Regional personnel. We then identified and prioritized areas of work where additional effort by the FAA could enhance the 80's Maintenance Program. Finally, we generated recommendations on the nature and degree of work that should be pursued by the FAA, or on their behalf, to enhance this Program.

CONCLUSIONS AND RECOMMENDATIONS

Based on our experience, the study team believes that the concept of centralized and automated operations underlying the 80's Maintenance Program is sound and viable. We have recommended seven major areas for additional work, which we believe will enhance the 80's Maintenance Program and ensure its benefits. We further believe the objectives of improved productivity and reduced operating costs are attainable if these recommendations are implemented.

In prioritizing these recommendations, we recognize that planning and implementation of the 80's Maintenance Program is an ongoing process. Many sector and system requirements and capabilities already exist. In all cases our recommendations are meant to build on the existing program.

All seven of the recommended areas for future work are important to the 80's Maintenance Program. The recommendations are summarized below in priority order based on the immediacy of action required. The first four recommendations are vital to the successful design and implementation of the current monitoring and control system. Recommendations 1, 2, and 3 are all related and deal with near-term technical needs of RMMS. Recommendation 4 relates to the associated 80's Maintenance Program management function. The final three recommendations are necessary to successfully plan and evolve the Program such that the desired operating cost reductions can be fully realized.

The seven major areas recommended for additional work are as follows:

1. Apply Distributed Processing Between the Remote Facilities and a Central Minicomputer.

Remote maintenance in the FAA depends on automated support from RMMS. To provide maintenance capability in the facilities, Remote Monitoring Subsystems (RMS) are planned as embedded or retrofitted hardware. To implement monitoring and administrative software, Maintenance Processor Subsystems (MPS) are planned as central minicomputers. It is the area between RMS and MPS which now needs to be assigned a role in RMMS functionality. With top priority, we recommend that the FAA:

- **Use distributed processing to support the many-to-one transfer of monitoring and control data between remote facilities and a central minicomputer.**

In particular, the FAA should reduce the load on the central minicomputer by distributing Input/Output (I/O) functions. For example, the "polling function" is necessary to control the transfer of data, but as the number of monitored facilities increases, it occupies more of the minicomputer's time. When polled for the purpose of alarm monitoring, a remote facility usually answers that no alarm condition exists. Such a request and response, leading to no action by the technician, has proved to be an inefficient use of minicomputer resources in the AT&T environment. We, therefore, recommend a distributed processing approach, in order to relieve the minicomputer of data communications overhead and allow for the application of specialized hardware to functions which are I/O intensive.

In addition, the FAA should standardize the messages to and from the minicomputer by distributing interface functions. For example, a "translation function" is needed to deal with the diversity of RMSs, which have already been defined for many remote facilities. Once maintenance information is transferred to the central minicomputer, it must then be processed, stored, and displayed to the user. The kind of information processing performed by

Monitoring and Control Software (MCS) depends on the functional content of messages, e.g., the definition of parameters. To increase the commonality of MCS software at the minicomputer, we recommend a distributed processing approach rather than extensive modifications to the RMS capability of facilities.

The FAA already plans to distribute one important interface function, namely the "concentrator function." This combines messages from the remote facilities in order to reduce communications costs. For example, a small-airport concentrator is being used by the Central Region for several facilities associated with the Instrument Landing System (ILS). In the telecommunications environment, more than 10,000 AT&T interface units have been deployed with processing capability beyond the concentrator function.

I/O functions and interface functions are closely related to communications lines provided by the Telecommunications Network (TCN) and message protocols defined by the Interface Control Document (ICD). AT&T summarizes this whole concept by using the term "telemetry" (see Figure 1). Telemetry hardware lies in the area between remote facilities and a central minicomputer. Telemetry functions are distributed, that is, processing occurs at both ends of a data communications line. We have focused on the telemetry area as critical to the current feasibility of RMMS, because the ability to transfer monitoring and control data in an accurate, efficient, and standard way is basic to implementing remote maintenance in the FAA.

2. Standardize the Requirements for MCS and Future RMSs.

The FAA plans to use minicomputers for a wide range of automated functions. In the case of RMMS, these functions are divided into two groups, known as MCS and the Maintenance Management System (MMS). We recognize that the monitoring area is more limited in scope, and thus more easily defined than the administrative area. MCS includes functions such as remote monitoring, certification, diagnostics, controls, adjustments, and failure anticipation. We recommend that the FAA:

- **Standardize the requirements for MCS and future RMSs; then further define the requirements for remote certification and failure anticipation.**

In the area of standardization, the FAA should extend its work beyond the ICD. Common functional requirements for broad types of remote facilities should be applied to those RMSs which are yet to be defined. Together with Recommendation 1, which introduces the telemetry concept, this allows a corresponding degree of standardization in MCS functions at the central minicomputer. Once this is implemented, the basic building blocks (RMS, telemetry, and MCS functions) of a remote monitoring and control system will be in place.

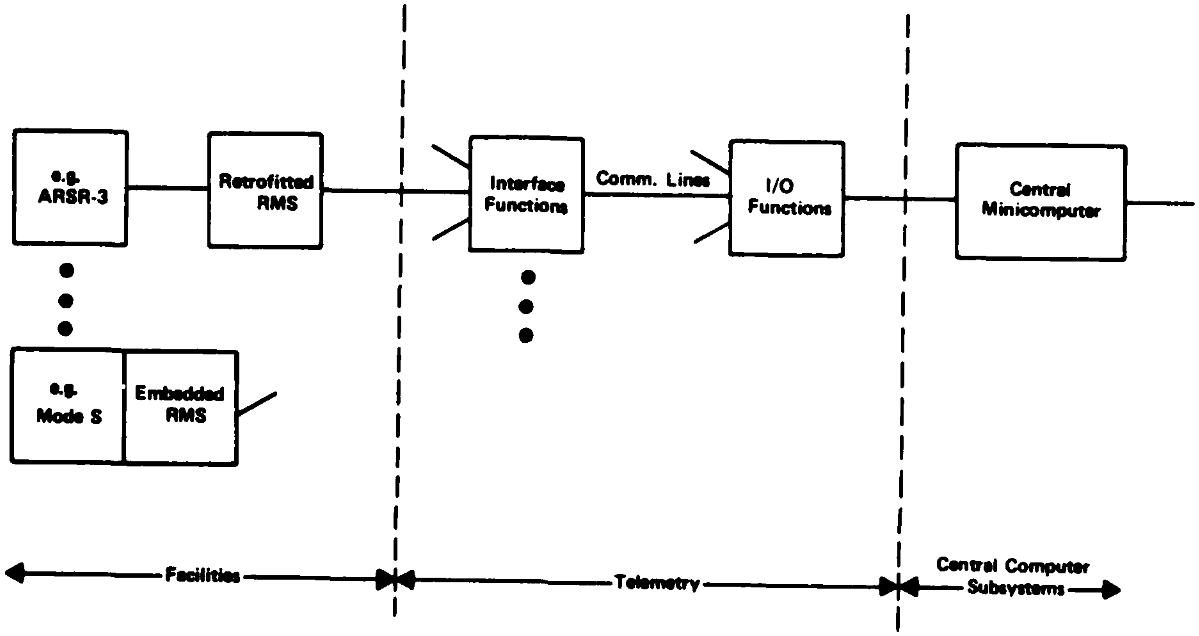

Figure 1. Telemetry Concept

The FAA should then further define the requirements for remote certification and failure anticipation, which have already been identified by the FAA as RMMS functions. For remote certification, the question is how to use automated analysis of parameter data to support decisions by the technician. For failure anticipation, the approach is first to determine which, if any, parameters may have a gradually degrading mode of failure. The sampling interval for such parameters is then chosen to detect the trouble condition before it reaches a failure state.

3. Determine the Hardware Specifications for MCS Functions.

The preceding recommendation modifies MCS by standardizing the functional requirements and by defining the detailed approach to remote certification and failure anticipation. To determine the resulting effect on hardware specifications, we recommend that the FAA:

- **Relate the sizing, selection, and location of MPS minicomputers to modified MCS requirements.**

The FAA should determine the number of minicomputers needed to handle input to the system (transaction rate and volume), functions within the system (software sizing), and data base requirements. AT&T experience with minicomputer-based systems has shown that the needed capacity often exceeds technical expectations, and that allowance should be made for about twice the estimated size.

The type of minicomputer hardware should be matched to the nature of its job. For example, MCS functions use a relatively static data base to identify remote facilities; MMS functions use a more dynamic data base, e.g., to update trouble history.

The location of minicomputers is also related to functional criteria. For example, MCS functions are more dependent than MMS functions on access to communications lines which serve the remote facilities, and on maintenance personnel who support high availability of the minicomputer.

4. Establish a Program Management Function for the 80's Maintenance Program.

To ensure controlled implementation of the 80's Maintenance Program, we recommend that the FAA:

- **Establish a Program Management function with the entire responsibility and authority for Maintenance Program planning and implementation.**

We found in our review that responsibility and accountability for the elements of the 80's Maintenance Program are distributed over several organizations, at Headquarters, the Technical Centers, and in the Regions. In our experience, the accountability for planning and implementation of the operations centers, systems, and associated capabilities in the maintained equipment cannot be distributed effectively across individual project organizations without increasing the program implementation risk. The functional integration of the technical and organizational elements can only

be assured with the overall view provided by a unified Program Management function.

Specifically, we suggest that the Program Management function have complete responsibility and authority for controlling the planning and implementation of maintenance sectors, RMMS, and RMS capabilities in the maintained facilities. In our experience, the success of automated maintenance systems has been limited when the remote maintenance capabilities being built into the maintained equipment could not be controlled by the manager responsible for the overall maintenance system design. In turn, planning for the needs of systems and maintenance sectors should be closely coordinated.

5. Establish an Operations Planning Framework for the 80's Maintenance Program.

In order to guide ongoing operations planning of the overall Program, we recommend that the FAA:

- **Establish an ongoing structured operations planning approach involving detailed functional analysis, and supported by quantitative studies.**

We became concerned about the operational self-consistency of the 80's Maintenance Program as a whole when the numerous individual activities were considered together. It is not clear how the various project maintenance approaches being planned will work together in the new centralized automated environment, since we were unable to identify a plan which depicts how all the people, systems, and facilities should interact to meet mission needs.

We recommend that the FAA adopt an ongoing operations planning approach with the following objectives:

- Provide a functional blueprint for an integrated maintenance approach.

- Provide a master plan from which the Regions can draft local plans tailored to the requirements of their specific local environments.

- Provide a reference point for planning the continuing change and evolution within maintenance operations.

- Provide a single common basis for the detailed systems engineering, development, deployment, and use of standard operations systems and procedures.

This planning should be supported by technical and quantitative analyses of user service needs, reliability, maintainability, availability, benefits, life cycle costs, and alternative plans. These analyses provide credibility for the content of the master maintenance operations plan, and are a basis for critical decisions affecting Program plans and procurements.

In our experience, work functions change with centralization and new ones appear with automation. This analysis is effective in early identification of new work functions and specification of interorganizational operational interfaces. As they are completed and documented, these analyses become the controlling design basis for standard sectors, manual methods, and RMMS and RMS capabilities in maintained facilities. The benefit of this particular approach is that it integrates early the sector, system, and facility requirements in a single high-level plan that is based on meeting mission needs in a cost effective manner.

6. Define a Functional Architecture for RMMS.

The area of minicomputer architecture is relevant to several near-term hardware and software decisions associated with the 80's Maintenance Program. We recommend that the FAA:

- **Design an overall RMMS functional architecture that supports the maintenance organization.**

A functional architecture provides the information necessary to properly select hardware and software elements within the RMMS system. System design decisions, such as sizing and location of computer equipment, are dependent on well-defined functions to be automated.

An overall functional architecture, such as the example shown in Figure 2, should be developed by allocating all functions identified during sector planning to specific subunits of the overall system. This example architecture is divided into three areas: facilities, the telemetry subsystem, and the central computer subsystems.

The facilities are assigned the functions required for on-site maintenance and for remoting the monitor and control information. The telemetry subsystem is allocated the functions of efficient monitor and control data transfer and data translation. Recommendations 1, 2, and 3 have already dealt with the design needs of the facilities and the telemetry subsystems. We recommend immediate implementation of this portion of the architecture. However, we feel that further planning is required to determine the proper central computer subsystems architecture.

In particular, we believe that one area of the central computer subsystems needs special attention. An early emphasis is needed to identify priorities and allocate all of the administrative functions that are to be automated by MMS within RMMS. MMS is currently being implemented, but our review did not identify strong links between the existing MMS requirements, the associated manual functions, and the maintenance tasks. Further, the requirements being defined for administrative support to be provided by the Maintenance Operations System (MOS) should be coordinated with the MMS requirements.

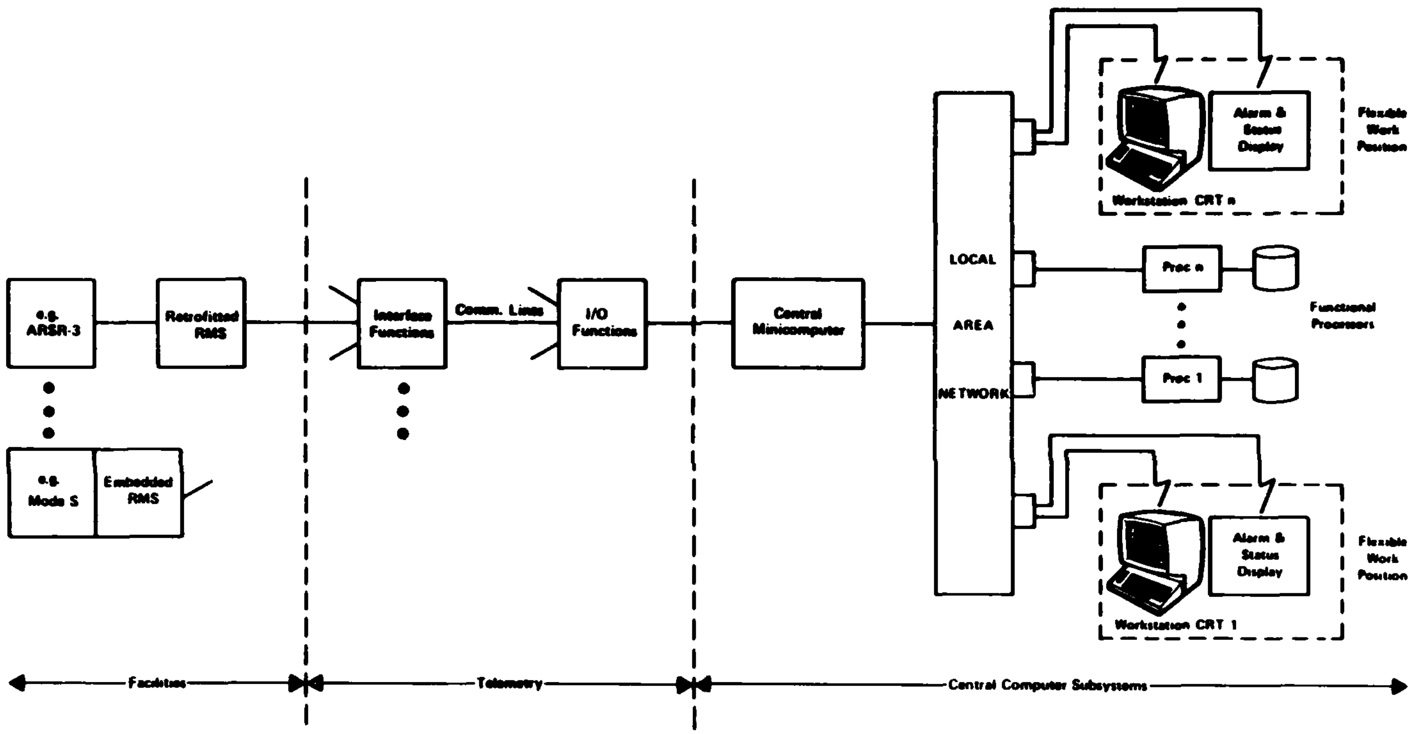

Figure 2. Example of RMMS Functional Architecture

Based on the planning approach described in Recommendation 5, we suggest that the allocation of operations functions to elements of the central computer subsystems be driven by the need for system flexibility and logical groupings of job functions. AT&T has found that centralization changes job functions and that automation presents opportunities for new functions. In addition, operations in maintenance organizations evolve in unpredictable ways. These changes result in new work positions and system communications needs.

Based on our related experience at AT&T, we suggest that certain functions be logically grouped together on functional processors. This supports the FAA grouping of functions in MCS and MMS. However, some of the functions presently assigned appear to be very large. Further, dividing these functions into logical subsets, which are small enough for minicomputer implementation, would allow for a phased, priority-based deployment of MMS. Subdividing these functions would also provide a lower risk development since problems in implementing one function will not delay the development of others.

As shown in Figure 2, flexible work positions should be designed to fit individual job needs. As noted above, centralization of maintenance will result in evolving work position needs. Flexible work positions facilitate this evolution of operations by making it practical to provide new human interface devices and capabilities.

Flexible communication arrangements are necessary to allow an organization to efficiently adapt to evolutionary changes, such as growth, new technology, reorganization, and facility reassignments. In this example architecture, the local area network provides the necessary flexible communications capability.

7. Establish a Model Sector Program.

In our review of sector implementation activities, we reviewed the plans to use Standard Sector Configurations as a national guide for implementing new General National Airspace System (GNAS) sectors. We support this approach based on AT&T experience with the Model Switching Control Center Program. We recommend that the FAA:

- **Expand the planned Standard Sector Configuration into a Model Sector Program that includes implementing the model and defining new work functions resulting from centralization.**

The Standard Sector Configuration would be enhanced by careful consideration of changes to work functions due to centralization and automation. In the AT&T experience, centralized maintenance changed work functions, created new work functions, and modified work flows in centralized organizations. Because of these changes, we recommend that the Standard Sector Configuration be expanded into a Model Sector Program which would include detailed characterizations of the new work procedures, interfaces and administrative and technical tools. Associated technician procedures for performing specific preventive and corrective maintenance tasks are logical extensions of the model

The final three recommendations are necessary to plan and evolve the 80's Maintenance Program in such a way that the desired operating cost reductions can be fully realized.

Based on our experience, the concept of centralized and automated operations underlying the 80's Maintenance Program is sound and viable. Also, the objectives of improved productivity and reduced operating costs are attainable if the recommendations presented in this report are implemented. We suggest that the FAA consider, if they have not already done so, incorporating the recommendations described in this report. Further discussion of the conclusions and recommendations outlined above is contained in the sections which follow.

SECTION 1

INTRODUCTION

1.1 BACKGROUND

In 1979, the FAA published the first Maintenance Philosophy Steering Group (MPSG) Report. This report described the 80's Maintenance Concept and set the FAA on a course of modernizing the maintenance operations associated with its National Airspace System (NAS) facilities. Updates to the MPSG Report have provided further definition of this effort, and it has become known as the 80's Maintenance Program. In early 1983, the FAA advertised their intention to have a company with related experience conduct a review of this Program.

AT&T has been planning and implementing similar programs since the late 1960s. Based on this experience, a Statement of Qualifications was submitted to the FAA, and AT&T was selected to provide a proposal for a study of the modernization program. When this proposal was accepted, FAA contracted with AT&T to conduct this study which began on October 24, 1983.

Under this contract, AT&T organized a multidisciplinary team of people, experienced in maintenance modernization programs, from AT&T Bell Laboratories, AT&T Technologies, and AT&T Headquarters to study the FAA maintenance modernization activities. This report presents the study team's results. The appendix describes related AT&T experience to serve as a detailed reference for FAA use. This appendix is proprietary information of AT&T and is provided in Volume II.

1.2 STUDY SCOPE

In accordance with the Statement of Work, Contract Number DTFA01-84-C-0010 titled "A Study of the FAA Remote Maintenance Monitoring System (RMMS)," the study team examined the 80's Maintenance Program with the objective of recommending work that should be undertaken to enhance this Program. In particular, the study team examined the following three subject areas:

1. Overall Program -- the 80's Maintenance Program, including the implementation plan, Program objectives, project responsibilities, and Program management.

2. Work Centers -- the FAA maintenance work locations, including the Airway Facility (AF) Sectors and the sector structure, the Maintenance Control Center (MCC), repair facilities, National Field Support Sectors (NFSS), and the people, their jobs, and their training.

3. Systems and Maintained Equipment -- the Remote Maintenance Monitoring System (RMMS), including the maintenance capabilities associated with the NAS facilities, and the computer based capabilities required to centralize and automate the operations.

1.3 STUDY APPROACH

The 80's Maintenance Program involves over 20 Divisions within the FAA (see Figure 1-1). The definition of the new sector organizations is shared between Headquarters and the nine AF Divisions in the Regions. System planning and implementation is distributed in a different way among organizations in Headquarters, the Regions, the Technical Center, and the Aeronautical Center. Development is provided both by contractors and in-house efforts. Procurements are provided on a national basis by Headquarters. Many of the Headquarters Divisions are also providing Remote Maintenance Monitoring (RMM) capabilities as retrofit packages for existing facilities or as part of the large number of new facilities projects being procured under the NAS Plan. Management of these various NAS Plan projects is also distributed among the involved Divisions.

In the initial phase of the study, we gathered information in each of the three subject areas of the study from meetings and individual discussions with FAA personnel. (See Table 1-1 and Figure 1-1 for the organizations the Study Team met with during the study.)

Based on this information, we identified areas where additional work by the FAA, or performed on their behalf, would enhance the 80's Maintenance Program. Finally, we generated specific recommendations concerning the nature and degree of work that should be pursued by the FAA in order to enhance the 80's Maintenance Program.

We made recommendations for additional effort in three areas:

- Systems Engineering
- Systems Development
- Systems Integration.

Systems engineering refers to the methodology for operations planning, organization planning, and systems requirements definition. Systems engineering recommendations address the following areas:

- Maintenance operations planning and RMMS architecture
- Functional architecture
- Maintenance sector requirements
- Human relations
- System requirements.

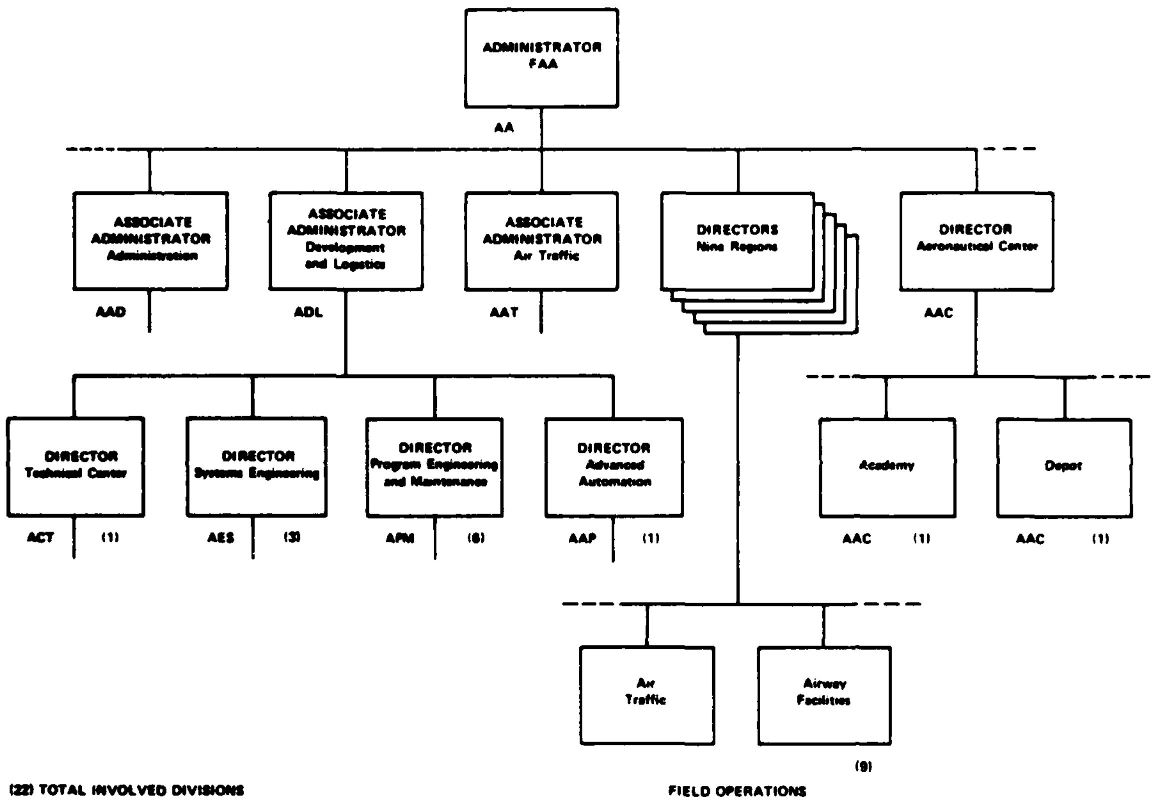

Figure 1-1. FAA Organization

TABLE 1-1

FAA ORGANIZATIONS VISITED BY THE STUDY TEAM

Location	Organization
Headquarters	AES-100, AES-200, AES-400 APM-100 through APM-600 AAP
Atlantic City	ACT, APM-160
Oklahoma City	AAC-400, AAC-900, APM-150
Regions	Central, Southern, Alaska,* Eastern†
Others	MITRE, Technology Applications, Inc.

Systems development refers to the mechanization of functions to support the operations plan and the design of maintenance organizations. Systems development recommendations address the following:

- Hardware and software development, deployment, and capacity requirements
- Interface requirements for new systems
- Sector implementation procedures.

Systems integration includes the management control and coordination of all activities required to implement the program. Systems integration recommendations address the following:

- Sector implementation, system installation, training, testing and evaluation, and contract maintenance
- The relationship between potential remote maintenance monitoring contractors and other contractors
- Program management and control.

Work in each of these areas affect the program, organizations, and systems necessary for a successful maintenance modernization program.

---

* Information provided by D. Zeller in Washington, D.C.

† Information provided by C. Marshall in Washington, D. C.

1.4 REPORT ORGANIZATION

The remainder of this report documents the study conclusions and recommendations. Section 2 presents a characterization of the FAA's maintenance operations including the overall Program, sectors and support systems, and maintained facilities. Section 3 contains the recommendations for systems engineering, systems development, and systems integration work that the FAA should pursue in order to enhance its Program. The appendix contains a description of AT&T's experience in maintenance operations planning, switching systems and central office equipment maintenance, and transmission systems maintenance.

The seven recommendations for major areas of work are identified in Section 3 with the same indented, **boldface** text used in the Executive Summary. Supporting recommendations are identified using indented text in the discussion following each major recommendation.

SECTION 2

CHARACTERIZATION OF THE 80'S MAINTENANCE PROGRAM

2.1 PROGRAM PLANNING AND MANAGEMENT

The FAA has responded to certain mission needs (e.g., high availability of functions to support the pilot and the air traffic controller) by formulating the objectives of the 80's Maintenance Program. These objectives should drive the definitions of maintenance functions needed in sectors, systems which support sectors, and facilities.

Some elements of the 80's Maintenance Program are planned and managed in the Systems Engineering Service (AES), others in the Program Engineering and Maintenance Service (APM), and others in the regions. AES-100 is responsible for maintenance concepts and policies, including the definition of NAS operational requirements (some of which are maintenance requirements). AES-400 has responsibility for planning, developing, and implementing the Maintenance Management System (MMS).

The Maintenance Engineering Division (APM-100) has responsibility for operational implementation of the Program in an integrated, orderly, and cost-effective manner. RMMS planning and procurements are centered in APM-600. Their responsibilities include the central processor hardware and software. APM-600 is not responsible for defining the maintenance capabilities needed in remote facilities. The individual facility project managers (e.g., for Mode S, RML, Airport Surveillance Radar (ASR)) determine these capabilities. This is achieved by interpretation of the Reliability and Maintainability Policy goals, and by taking into account the NAS design objectives.

The Regional AF Divisions have responsibility for implementing the 80's Maintenance Program in the field, including both the sector organizational aspects, and the equipment deployment. Some experimental Remote Monitoring Subsystem (RMS) prototype concepts are also formulated in the regions and developed at the Technical Center.

Representatives of these organizations (except for the facility project managers) come together in several forums, such as the MPSG, RMM Steering Group (RMMSG), Lead Sector Steering Group (LSSG), and Lead Sector Software Steering Group (LSSSG). These steering groups are used to resolve issues of common concern. This provides numerous opportunities for regional input to the planning process.

2.2 MAINTENANCE SECTORS

2.2.1 Maintenance Organizations

AF Sectors are the principal field element in the FAA maintenance organization. They are subdivisions of the AF Division of each Region. Sectors are responsible for the maintenance of the NAS facilities assigned to them. There are two types of AF Sectors: the General NAS (GNAS) Sector and the Center or Air Route Traffic Control Center (ARTCC) Sector. The GNAS Sector is responsible for facilities within a large area. It is a dispersed organization with technicians at work locations throughout the area for which it has responsibility. The GNAS Sector is responsible for typically 300 to 400 facilities of the following types: navigation aids, communication equipment, radar systems, automated systems, visual aids, and environmental systems. The other AF Sector type, the Center or ARTCC Sector, is responsible for the facilities located within the ARTCC building, which include communication equipment, computer systems, and the Air Traffic Control (ATC) positions.

The AF Sectors obtain support from several national organizations. The NFSS for Automated Systems, in Atlantic City, New Jersey, provides support for computer based systems, such as the NAS Automated Computers, the Maintenance Processor Subsystem (MPS), the Remote Center Air Ground (RCAG) RMS, the Mode S radar, and the ASR-9 radar. This responsibility includes managing procurement of modifications to the systems software. The NFSS for Non-Automated Systems, in Oklahoma City, Oklahoma, performs a similar role for power systems, generators, and most radars. Other national support groups are the FAA Depot, which provides supply support and complex equipment repair, and the FAA Academy, which provides hands on training and management of the overall training program.

The study team found the GNAS Sector to be particularly complex because its geographic responsibility is different from the ATC service areas. For example, the Flight Advisory Areas of the ARTCCs are not coincident with GNAS Sector boundaries. Some sectors have their facilities connected to one ARTCC. Others interface through several ARTCCs. For example, the Kansas and Missouri Sectors have most of their facilities connected to the Olathe ARTCC. All the Alaska Sectors interface with the Anchorage ARTCC. The Nebraska and the Iowa Sectors, however, interface with their facilities through two ARTCCs. Additional complexity results when the Automated Flight Service Station (AFSS) has Flight Plan Areas that are different from the sector areas. The operational complexity that results from these differences in boundaries is a significant characteristic of GNAS Sectors.

2.2.2 Maintenance Operations

Maintenance operations of the FAA are changing in several significant ways. The current operations are characterized by extensive preventive maintenance activities, on-site repair of defective components, and a spare parts inventory maintained on-site and provisioned from a central depot. This operations program requires that a highly skilled technical workforce be near the NAS

facilities and dedicated to work on the same facilities. Trouble notification comes either from the equipment itself or from Air Traffic (AT) personnel notifying the appropriate AF personnel.

The 80's Maintenance Program changes the operations by implementing RMMS, which will allow remote monitoring of facility status and control to a staffed location, the MCC. The program will allow the maintenance staff to remotely monitor the facilities from central work locations, and under the direction of the specialist at the MCC. Trouble notification will come from RMMS. RMMS will allow the maintenance sector specialist to remotely monitor and control the GNAS facilities, investigate troubles, and dispatch the workforce as needed.

Among the maintenance activities that require frequent site visits are periodic preventive maintenance and certification. Certification is a legal requirement on the maintenance force. It is the process of ascertaining that certification parameters are within specified performance limits and of recording the parameters on an official record signed by the maintenance technician. If an air traffic incident occurs, this record is to be available as legal proof that the FAA equipment was operating properly.

2.2.3 Sector Planning Activities

Within the FAA, APM-100 is establishing the broad guidelines for the AF Sectors. Sector responsibilities and the basic organizational structure are defined in Order 1100.127B; the sector size is established from data in the Facilities Master File and the procedures in Order 1380.40. Some projects that will effect sector planning are Engineered Staffing for AF Sectors, Lead Sector, Standard Sector Configuration, AF Sector Headquarters Space, and Maintenance Control Centers.

Each region transforms these national guidelines into functioning organizations in their area. The factors that the regions consider when establishing sectors are the travel time between work and facility locations, the mix of facility types in the sector, and the number of technicians required to maintain the facilities. The regions are asked to develop Regional Implementation Plans that start with the existing AF Sector organizations and achieve the goals outlined in the 80's Maintenance Program. The goals are to reduce the number of sectors from 115 to 65, to reduce the number of staffed work locations from 1000 to 300, and to implement remote monitoring and control of the facilities while maintaining the importance of the technician's job.

Through the Lead Sector Program, each region is trying various organizational structures and developing tools necessary for centralized operations in their area.

2.3 REMOTE MAINTENANCE MONITORING SYSTEM OVERVIEW

This section summarizes the FAA's current plans for design and development of RMMS. Figure 2-1 summarizes the present hardware architecture of RMMS and gives examples of the FAA facilities to be remotely monitored. It focuses on items being used by the Central Region because this region was visited by the study team. Part of RMMS is presently being deployed (solid lines), but most of the overall system is still to be developed and deployed (dashed lines).

2.3.1 Remote Facilities

The FAA has a large number and variety of navigation, landing, surveillance, and communications facilities. Air-to-ground communications are provided by radio equipment such as the RCAG. Airways are defined by navigation aids such as VORTAC. Surveillance radar (e.g., Air Route Surveillance Radar (ARSR), ATCBI, ASR, Mode S) detects primary and/or secondary targets. Landing systems (i.e., ILS, MLS) provide horizontal and vertical guidance to the runway. Most of the new FAA facilities have already been deployed or defined as part of the solid-state replacement program.

2.3.2 Remote Monitoring Subsystem (RMS)

Maintenance capability is being provided for new and existing remote facilities. For new facilities such as ASR-9, MLS, Mode S, and the second-generation VORTAC, embedded RMS capability is being provided. For existing facilities, such as RCAG and ARSR-3, RMS and the associated Sensor Interface (SI) will be added as new components. In the Central Region, the study team was shown RMSs retrofitted to an Air Traffic Control Beacon Interrogator (ATCBI) facility, a Medium Airport Lighting System Runway (MALSR) facility, and the Glide Slope (GS) part of an ILS. A Limited Remote Control (LRC) unit is also being used there for the tube-type ARSR-1,2 and as an interim arrangement for ARSR-3. Clearly, the FAA has done considerable work in the RMS area. There is, however, a diversity of maintenance capability, e.g., with respect to the parameters and controls provided.

2.3.3 Telecommunications Network (TCN)

The data communications lines which transfer monitoring and control data between remote facilities and a central minicomputer are part of the TCN. They range from microwave radio channels (e.g., for ARSR) to shared voice/data channels (e.g., for RCAG). A communications protocol is also needed to transfer data, e.g., by establishing link-control procedures and message formats. The FAA is currently updating the Interface Control Document (ICD) for this purpose.

RMMS

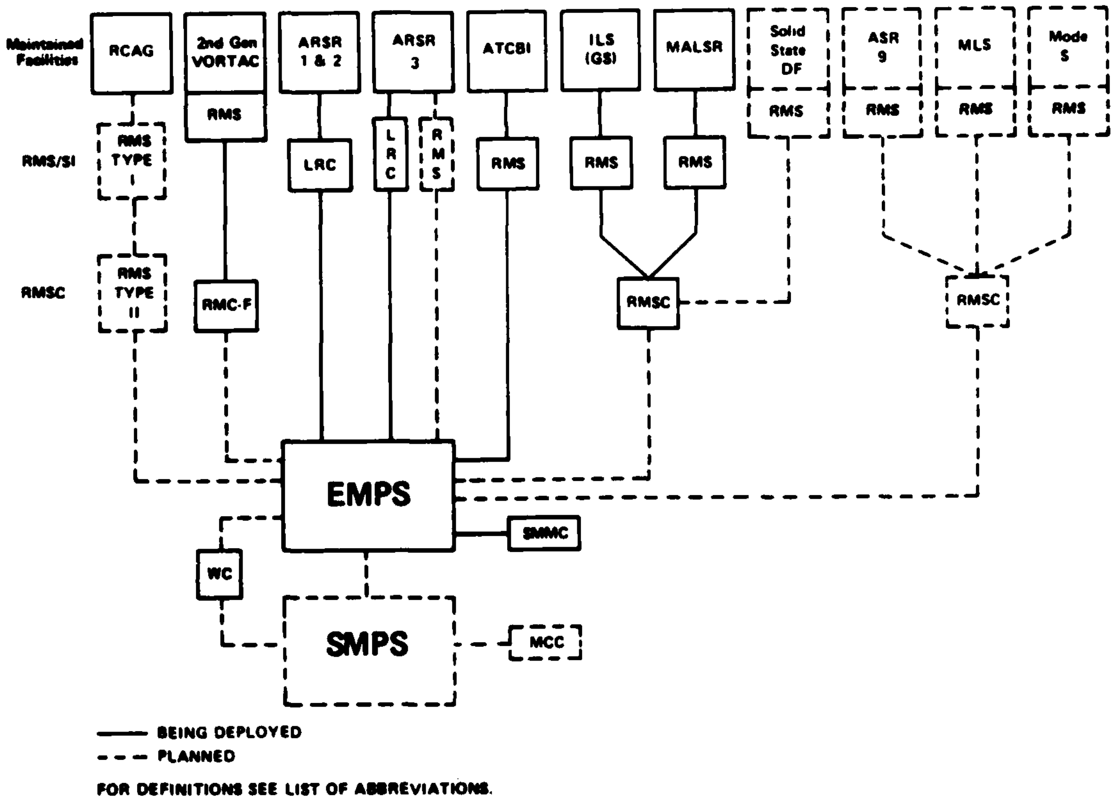

Figure 2-1. RMMS

To reduce the number of data links required to a central minicomputer, the FAA has introduced the concept of an RMS Concentrator (RMSC). The study team was shown a small-airport concentrator developed by the Central Region. The Technical Center at Atlantic City has also built and tested a larger prototype RMSC. Earlier, the concentrator function was implemented in the RMC-F for VORTAC and planned in the RMS Type II for RCAG. The bulk of RMMS data processing, however, is left for the central minicomputers.

2.3.4 Maintenance Processor Subsystem (MPS)

The FAA has described an En Route MPS (EMPS) for the ARTCC Sector and a Sector MPS (SMPS) for the GNAS Sector office. At present, twenty-three minicomputers have been purchased for deployment as EMPSs. Many remote facilities are expected to send messages via EMPS to SMPS, as shown in Figure 2-1, because the ARTCC is a communications hub. Some remote facilities, however, will be linked directly to SMPS when this communications route is more readily available. The minicomputers will support user terminals at the GNAS Sector office, work centers, and the ARTCC Sector.

The software to be run on MPS hardware consists of two distinct packages: Monitoring and Control Software (MCS) and the Maintenance Management System (MMS). MCS is planned to include functions such as remote monitoring, certification, diagnostics, controls, adjustments, and failure anticipation. MMS is planned to include functions such as record-keeping, trend analysis, and problem/solution history. This is only a first-level division of RMMS functions. Currently, the development of MCS for ARSR-LRC is being integrated with that for RCAG-RMS. As an interim arrangement, the Central Region is developing a Maintenance Operations System (MOS) which will perform a subset of MMS functions. MMS provides a wide variety of administrative support for users ranging from on-site technicians to headquarters personnel.

SECTION 3

RECOMMENDATIONS

3.1 SYSTEMS ENGINEERING

3.1.1 Program Planning

Based on the study team's characterization of the 80's Maintenance Program, we find many analogies with the planning needs for remote maintenance monitoring identified and resolved within AT&T over the past decade. In this section we relate our program planning experiences to the FAA environment and make recommendations which can improve the FAA's program planning and implementation processes.

3.1.1.1 Planning Methodology

Considerable maintenance planning and implementation work is underway at the FAA. Examples are the MPSG reports, the various Program implementation and operations plans, the procurement of solid state facilities, and the work of the Regions in introducing remote monitoring and in implementing lead sectors.

We became concerned about self-consistency in the Program as a whole when the numerous individual planning and implementation activities discussed in Section 2 were considered together. Our view is that many of the efforts are proceeding on individual paths. We found that project managers generally shared that concern. It is not clear how the approaches being taken for implementation match the 80's Maintenance Program. Some equipment (e.g., ICSS Type II & III) will be maintained by contractors, others (e.g., FSAS program) will require on-site maintenance personnel, and others (e.g., ASR-9) will require dispatches from a central location. There will be different sparing approaches for facilities in the GNAS Sector (e.g., RML and SGV), and there will be different maintenance messages provided by similar equipment (e.g., types of radar).

The NAS facility projects are planned to meet individual AF service maintenance objectives and mission-oriented needs of the pilot and AT. It is not clear how the individual project maintenance approaches being planned will work together in the new, centralized, automated sector environment since we were unable to identify a plan which depicts how all the people, systems, and remote facilities should interact to meet service and mission needs.

In similar situations, AT&T has found that a planning and implementation methodology is needed which permits different individual project (or regional implementation) maintenance approaches when appropriate, while ensuring that the necessary features, interfaces, functions, and capabilities are available across sectors, systems, and facilities. This methodology is operations planning, a structured systems engineering discipline which introduces a large measure of program planning control and

risk reduction. It does this by tying detailed sector and system plans and facility procurements back to high-level benchmark views of how and with what tools maintenance people will meet objectives.

To enhance the overall Program, we recommend that the FAA:

- **Establish an ongoing structured operations planning approach involving detailed functional analysis, and supported by quantitative studies.**

AT&T's operations planning approach is described in more detail in the appendix. An important element described there (see Sections A.1.5 and A.2) is a structured planning process. Figure 3-1 shows the 80's Maintenance Program overlaid on this planning concept. By structuring the planning functions and providing dynamic interactions between the elements, a traceable path is created between high-level maintenance concepts and detailed sector, systems, and facility operational requirements and implementations. The study team had difficulty finding such traceable paths in the current planning for the 80's Maintenance Program.

Operations planning generates consistent outputs in increasing level of detail in moving through the planning process. For example, the most general outputs are typically high-level views of a sequence of sector, system, and facility interactions to accomplish complete maintenance tasks. These are used as benchmarks in the more detailed planning.

This does not imply that there must be a rigid top-down planning sequence. In AT&T maintenance planning, concurrent work is going on at all levels of detail, just as it is in the various divisions of the FAA. The operations planning approach provides the framework, the incentive, and the mechanism for taking advantage of all that exists today, identifying and resolving current and future issues, and proceeding towards self-consistency in a large and complex program. Of course, inputs reflecting regional and national views are included at all stages and levels of the planning. The various FAA steering groups are attempting to address the problem of consolidating these views.

The total operations planning approach to maintenance planning complements Integrated Logistics Support (ILS). Operations planning fully integrates ILS and all other maintenance-related elements with the critical human dimension, ensuring that the actual functional needs of the people performing the work in real time will be met. ILS focuses, for example, on the maintenance tasks, supply support, transportation, test equipment, and on the personnel and training skills needed to perform the work. Operations planning produces the self-consistent, detailed, integrated view of how and with what computer-based functions people will best perform the tasks and meet mission needs. In a decade of experience, we have validated this approach for effectively planning and implementing maintenance modernization programs to realize the intended program benefits.

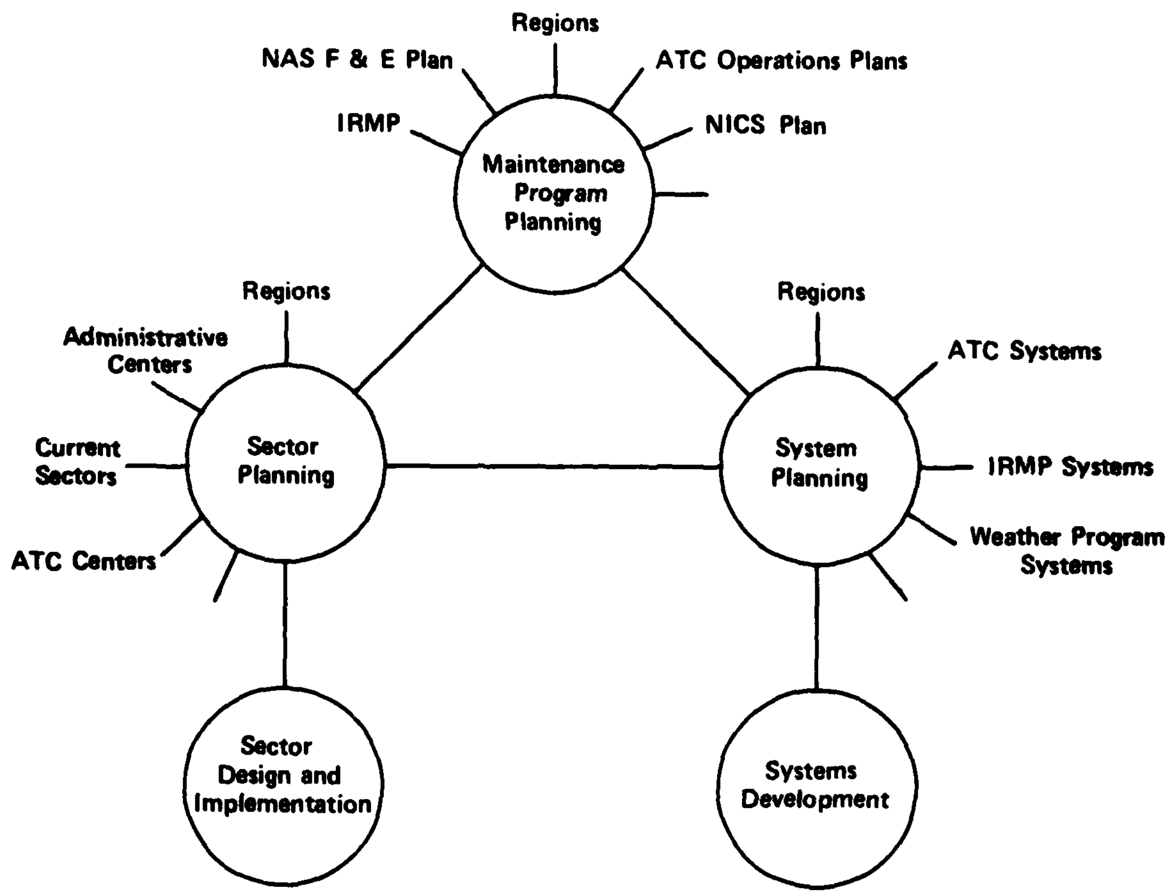

Figure 3-1. Structured Planning and Implementation Concept for the 80's Maintenance Program

Operations planning originated at AT&T and has evolved in response to the need to ensure that significant maintenance benefits were obtained from AT&T's multi-billion dollar, ten-year modernization initiatives. For example, between 1975 and 1980, the number of AT&T working lines increased by 20% to 83,000,000. The switching maintenance force had been projected to increase during this same period by 13% to accommodate this growth. However, as a result of centralized automated operations and modernization using new technology, the actual maintenance force was 30% less than the projected level.

This planning approach requires a firm analytical basis. AT&T's experiences in centralized automated maintenance planning have led to a recognition of the importance of technical and quantitative analyses in this field. For example, such studies facilitate sound program control and provide a way to trace whether benefits are really achieved. They also play a key role in ensuring logical, consistent planning decisions.

In implementing the 80's Maintenance Program, the FAA has critical concerns in quantifiable areas such as reliability, maintainability and availability, life cycle facility costs, and new maintenance sector organizational concepts and scenarios. The Transportation Systems Center is studying some of these areas, following initial studies by the MPSG-I group. We support the need for further analytical work in such areas. This work is of value when integrated into planning activities.

3.1.1.2 Planning Activities and Studies

At the Maintenance Program Planning level (see Figure 3-1), numerous activities are initiated by AT&T. The following are some examples which the FAA should consider as a basis for further work:

- Identify mission-related maintenance needs and long-term maintenance objectives (e.g., reduced operations costs and increased productivity).

- Formulate overall maintenance operations processes depicting the sequence of work functions (involving people, systems, and facilities) required to accomplish maintenance-related tasks (e.g., facility certification).

- Address sector networking interfaces and communications needs, and interdependent facility program needs as they relate to support of the maintenance program.

- Plan the operations transitions from the present environment into the near- and long-term environments.

- Provide guidelines for centralized work force planning in the transition and long-term environments.

- Plan the maintenance of new technologies (e.g., distributed processing, satellites, fiber optics).

Typical areas where AT&T has found quantitative and technical studies of maintenance needs to be of value, and where we expect benefits to the FAA are:

- Analytical evaluation of mission needs.
- Rigorous analysis of reliability, maintainability, and availability needs to ensure that requirements are consistent across projects and lead to defensible maintenance policies based on an internally consistent maintenance plan.
- Study of life cycle costs, including program trade-offs, e.g., alternative ways of meeting facility availability versus life cycle cost.
- Study of operations cost models leading to, for example, prioritization of functions to be automated.
- Assessment of alternative sector configurations according to reliability/cost factors and operational needs.
- Assessment of alternative maintenance approaches (e.g., structured maintenance).
- Evaluation of maintenance communications network needs.
- Quantitative assessment of the impact of new technologies on maintenance program evolution.

3.1.1.3 Extending the 80's Maintenance Program Planning

In our review, the relationship between the 80's Maintenance Program and the maintenance activities needed for the following three types of facilities emerged as an issue:

1. Facilities in the ARTCC Sector will include both existing and new facilities, e.g., Voice Switching and Control System.
2. Telecommunications Network (TCN) facilities will include all the components (e.g., RML and National Airspace Data Interchange Network) which comprise the integrated network providing communications for maintenance and for air traffic control operations.
3. Computer Facilities include computers and their associated software which provide support for air traffic control, flight service, and maintenance operations (e.g., Center Weather Processor computer, RMMS computers, and 9020 Rehost computers).

For facilities in the ARTCC Sector, it is our understanding that interfaces have been identified between RMMS and certain facilities, e.g., the Voice Switching and Control System. We also learned that the SMMC will have RMMS support, and will interface operationally both with the GNAS Sector and with Air Traffic Control operations in the ARTCC.

We suggest further clarification of the maintenance operations needs in the ARTCC Sector beyond the work currently proposed. Since it is staffed 24 hours a day, the maintenance operations plans for this sector will likely be different from those for the GNAS Sectors. If the definition of a maintenance plan for the ARTCC Sector were accelerated, these maintenance needs could be more effectively integrated into the 80's Maintenance Program, and the differences in maintenance plans taken into account.

In our experience, telecommunications network maintenance is critical for two reasons. First, it is the transport media for RMMS data communications, and its reliability, maintainability, and availability characteristics must be considered as part of the 80's Maintenance Program. Typically, we have found that the maintenance requirements on communications networks need to be more severe than the requirements on maintained facilities. This is because remote maintenance of facilities is dependent upon a functioning network. Second, the telecommunications network must be maintained as a single entity with the ability to remotely pinpoint trouble to specific network elements, such as a switch or transmission link. During our review, we found that maintenance planning is being done for some network elements (e.g., RML). However, it was not clear whether such planning is underway for the telecommunications network as an entity.

In the area of maintenance for computers and their associated software, AT&T experience suggests that centralized maintenance is applicable in two ways. First, when a number of computers can be collocated (e.g., at the ARTCC), a smaller computer maintenance staff is needed. Second, the maintenance, administration, and change control of the associated software may be more effective when performed on a centralized basis, with software changes downloaded over the telecommunications network. Such control might be performed from a centralized location, e.g., at the NFSS in Atlantic City or from FAA Headquarters.

In summary, we believe additional benefits may be possible by extending the 80's Maintenance Program to include these three types of facilities.

3.1.2 Planning Centralized Sectors

This section makes recommendations for systems engineering work by the FAA to improve its planning activities for maintenance organizations. AT&T has planned and implemented many types of organizations engaged in centralized maintenance and monitoring of facilities. Some of the organizations that have been planned and deployed are in Table 3-1. The study team found that similar organizations were being planned for centralized maintenance and monitoring of NAS facilities. Some of the organizations we found the FAA to be planning are shown in Table 3-2. The recommendations made by the study team in this section are based on experience at AT&T for planning and implementing maintenance organizations, and the analogies we saw in FAA planning.

TABLE 3-1

AT&T MAINTENANCE ORGANIZATIONS

Name	Typical Responsibility	Number Deployed
Switching Control Center	Switching Systems	300
Facility Maintenance and Administration Center	Transmission System Equipment	56
Special Service Center	Leased Voice, Data and Switched Services	100
Maintenance Center	Transmission Links to Customer Premises	50
Electronic System Assistance Center	Escalation of Field Problems to a Regional Support Group	23
Product Engineering Assistance Center	Escalation of Field Problems to the Designers	7

TABLE 3-2

FAA MAINTENANCE ORGANIZATIONS

Name	Typical Responsibility	Number Planned
GNAS Sector	GNAS Facilities	65
Center Sector	ARTCC Facilities	23
National Field Support Groups	Technical Assistance and Modifications	2

The FAA has provided broad guidelines defining the maintenance sectors at a national level. Each region, however, has the task to transform these national guidelines into functioning organizations in their area. This approach is similar to the way AT&T was planning centralized maintenance organizations in the early 1970s. The result for AT&T was a diversity of implementations. Each entity developed its own methods for nationally supplied tools and developed their own tools for what they thought were special needs. Some entities were partially effective in achieving the projected benefits. In general, however, all of the expected benefits were not being achieved, and there were overall inefficiencies. In AT&T, the field did not have the resources to develop effective methods and procedures because field personnel were driven by the need to deal with current maintenance problems. To improve this situation, AT&T established within AT&T Bell Laboratories the operational planning functions described in Section 3.1.1. This planning provided more detailed guidance for maintenance organization planning that focused on jobs and job needs, function definitions, organizational baselines, standard job descriptions, and standard automated system functions.

Based on this experience, the study team believes that more detailed sector planning is needed at the national level to support the regions because it will reduce the risk and help realize greater program benefits. Therefore, we recommend that the FAA:

- Perform detailed functional analysis and decomposition of all maintenance processes required at centralized and remote work stations in the sector.

At AT&T, this detailed functional analysis uses the high-level functions defined at the program planning level as described in paragraph 3.1.1.1. These functions are analyzed and decomposed into supporting activities. (The AT&T approach to this work is described in Sections A.2 and A.3 of the appendix.) For example, the following is a partial list of typical functions that are necessary for AT&T maintenance operations. Typical subdivisions, as a result of functional decomposition are shown in Figure 3-2.

- Maintenance functions are tasks directly related to the maintenance of the facilities.

- Administrative functions are the administrative tasks involved in running the sector, e.g., record keeping, certification. These functions include much of the record keeping involved in operating a sector.

Detailed functional analysis further analyzes each subfunction to identify the inputs, outputs, the required resources, the procedures to be carried out, and the performance criteria (see Section A.3.2 of the appendix). When this analysis is completed, a functional system architecture is developed, the candidates for automation are selected, and the methods required to use the automated tools are developed. Output from this activity drives the Sector Design and Implementation activity and the System Planning activity (see Figure 3-1). One output is identification and documentation of the jobs in a maintenance organization and of the methods needed by both the technicians and managers to accomplish their jobs. These are used as inputs to the

Maintenance Functions	Administrative Functions
-Trouble Detection -Service Restoration -Alarm Notification -Trouble Investigation -Trouble Verification -Trouble Isolation -Equipment Repair -Status and Control Information Transfer	-Inventory Control -Spare Parts Management -Equipment Modifications -Problem/Solution History -Trouble Ticket Management -Work Scheduling -Data Base Management

Figure 3-2. Representative Functions Necessary to Support an AT&T Maintenance Organization

Sector Design and Implementation system engineering activity. The second output is used as input to the Systems Requirements activity. This output provides the basis of a functional architecture, a description of the functions to be automated, and assigns them to automated systems or to the maintained facilities. The benefits for AT&T were the following:

- Consistent plans were provided for complex organizations.
- Methods work and systems planning was consolidated into one national systems engineering organization.
- Systems were developed that supported the maintenance jobs, met the user requirements, and could be used in most field environments with few field changes.
- Standard organizational designs were provided that can be used by the field as a guide for the implementation of effective organizations (see Section 3.2.3).

3.1.2.1 Maintenance Functions

In our experience at AT&T, defining maintenance systems requirements follows the analysis of the responsibilities of the people, both technicians and managers. The job descriptions of the individuals at different proposed work positions need to be planned and documented, and overlapping responsibilities removed. This process begins by analyzing existing jobs and then expands to include new jobs created by centralization. System features are then defined to support these jobs.

The study team noted several activities addressing elements of this need. The identification and documentation of the real-time maintenance functions of RMMS have been specified by the FAA. It is not clear, however, that the job requirements in the sector are the basis for these Level 1 requirements. We found in the study that maintenance tasks in the centralized environment are addressed in terms of the tasks performed by the technician now on site. The needs of both manager and technician should be addressed in the centralized environment.

AT&T's Switching Control Center has a Surveillance Position. Its role is to respond to remote equipment alarms and to protect service by taking immediate corrective action. The Surveillance job requires system features different from those needed by the technicians in the field. In the FAA environment, the MCC project may address this need, but it must also provide a job description as one output to avoid assignment of overlapping responsibilities. In the Central Region, for example, the responsibilities of the field technician and the staff in the prototype MCC may overlap. The result is a complex system design that must send facility alarms to several places, and complex operations where several work stations are accountable for responding to alarms. Therefore, we recommend that the FAA:

- Identify and document sector jobs (including management, supervision, and technicians) and address overlapping responsibilities.

3.1.2.2 Administrative Functions

Administrative functions, like maintenance functions, are crucial to the performance of the jobs of a line maintenance organization. AT&T's analysis of administrative functions based on job needs led to logical groupings of functions and to the development of a number of functional systems that support these functions. Typical areas studied included the jobs of the people using the systems, the size of the software package required, the frequency of user access, the required response time, the size of the data base, and the existence of a system that could be modified to provide the necessary capabilities. These study results were used to define a system engineering plan which was used to guide system development. Table 3-3 lists some of the administrative support systems that were developed as a result of this functional analysis. The study team found that the FAA had identified some of the needed administrative functions and had assigned them all to a single system, MMS (see Table 3-4). Based on AT&T experience, several of these functions may require large software packages and significantly load the processor. To mitigate this, MMS could be subdivided. We recommend that the FAA:

- Analyze the requirements that identify the inputs, outputs, required data bases, interfaces to other functions, and the evaluation criteria for each administrative function, and then map logical groupings of functions to separate systems.

We note that several operational scenarios have been developed to describe how FAA technicians and managers will use the system. Based on our experience these scenarios need to be related to specific job needs.

We also observed an activity, parallel to MMS, associated with the development of the MOS in the Central Region. AT&T has found that the development of experimental software packages can be an effective way under certain circumstances to try new methods, which then lead to the development of requirements for the final system. In the FAA, we found that the MOS will be replaced by the MMS when it is implemented. MOS should be used to meet near-term needs, to validate the requirements for MMS, and to make sure the tasks performed by people are supported by the system features.

3.1.3 Human Relations

With respect to NAS maintenance, the FAA is to be commended for early anticipation of potential human relations problems and for launching numerous efforts which will help avoid their occurrence or alleviate their impact. Among these efforts are the Human Resource Plan, classification of Systems Specialists, career planning, certification of Systems Specialists, staffing standards for AF Sectors, and computer based training.

TABLE 3-3

AT&T SYSTEMS SUPPORTING ADMINISTRATIVE FUNCTIONS

System Name	Function
CATLAS	Pattern Analysis of Failures to Identify Faulty Components
SCANS	Software Distribution and Administration
COMMS	Scheduling and Controlling Routine Maintenance
TIRKS	Circuit Record Keeping
PICS	Plug-in Inventory Control

TABLE 3-4

FAA ADMINISTRATIVE FUNCTIONS

Subsystem Name	Function
MMS	Facility Record Logging
MMS	Inventory Tracking
MMS	Facility and Service Performance Reporting
MMS	Facility Modification Tracking
MMS	Certification and Preventive Maintenance Work Scheduling

The study team suggests, however, that there are features of this human relations effort that might be improved. This section discusses these features and suggests for FAA consideration some approaches based on AT&T experience in similar circumstances. Two issues are of prime concern:

- employee communications and
- quality of work life.

3.1.3.1 Employee Communications

Communicating with employees about the future mode of operations is an important human relations concern. The study team was unable to identify a consistent approach to employee communications concerning the impending transition. Some overall direction in this area seems needed. While audio-visual presentations and widespread dissemination of planning documents are excellent approaches, the study team recommends that the FAA:

- Conduct periodic face-to-face discussions, such as in supervisor/subordinate conferences and skip-level conferences with immediate supervisors not present.

As well as effectively distributing information, these meetings allow the organization to benefit from the experience and knowledge the technician brings to the situation. This was helpful to AT&T not only in terms of providing information to make new centers and systems more useful, but also to create in technicians a sense of ownership of the new mode of operations.

Another aspect of employee communications related to changing operations is informing interfacing organizations of these changes. In our experience, there is a particular tendency to overlook communicating to these interfacing organizations which are vital to the maintenance organization's ability to fulfill its mission. In the FAA, advance work is needed as well as continuing efforts to maintain good relationships with organizations such as AT.

In light of the importance of employee communications, additional emphasis is needed as part of a concerted program on communications.

3.1.3.2 Quality of Work Life

In AT&T's experience in the early days of maintenance centralization, there was a tendency for the morale of the field work force to decline as measured by surveys. It was found also that managers tended to remain largely unaware of what was happening. As a result, the human relations issue became as much one of understanding morale in the present environment as one of accommodating employees in a changed environment. Accordingly, since people with high morale adjust to change easily while those with low morale do not, it is recommended that the FAA:

- Include in the national program for the future mode of operations and employee communications the task of evaluating employee morale and quality of work life in the present setting.

- Address improvements in the present mode of operation to bring about a situation more conducive to smooth transition if deficiencies in morale and quality of work life are found.

In summary, the study team believes that the FAA should continue the current human relations efforts while making an attempt to further integrate them into the 80's Maintenance Program.

3.1.4 RMMS Requirements

This section discusses the RMMS functions that have already been identified by the FAA and the effort needed to write system requirements. This includes the RMS capability to be retrofitted or embedded in remote facilities and the MCS to be implemented on central minicomputers. The study team recommends that the FAA:

- **Standardize the requirements for MCS and future RMSs; then further define the requirements for remote certification and failure anticipation.**

This work is applicable to near-term decisions concerning minicomputer hardware and software.

3.1.4.1 Standardization of Requirements

In the telecommunications environment, there has been a continuing trend toward standardization. The first goal in this area was to ensure transmission compatibility so that different elements of the network have a consistent way of handling voice, data, and video signals. More recently, however, there has been a corresponding effort to standardize the automated maintenance functions, so that all telecommunications equipment can work together with AT&T's minicomputer-based systems. In the FAA environment, the study team supports the continuing effort to specify a standard communications protocol, i.e., the ICD. We recommend that the FAA extend its work in this area beyond interface requirements in order to:

- Standardize functional requirements for those RMSs which are yet to be defined.

- Standardize functional requirements for the MCS.

- Standardize the human interface to RMMS.

The first item should be based on a characterization of the broad types of remote facilities from a maintenance point of view. In the AT&T environment, there is a Technical Reference which introduces the AT&T approach to remote maintenance, defines broad types of transmission equipment, and specifies the alarm indications required for each type.

The second item depends in part on the first. To the extent that the functional content of messages can be standardized for remote

facilities, then information processing by MCS software can also be standardized. For example, if messages have the same format but different meaning, then common software is applied only to functions such as information storage and display.

The third item deals with system requirements at the human interface, e.g., English messages and screen displays. A degree of standardization allows the technician to communicate with different RMMS functions in a similar way.

3.1.4.2 Further Definition of Requirements

Among the basic functions identified by the FAA for RMMS are remote certification and failure anticipation. Each is a complex area that can have an effect on the kind of processing performed and on the quantity of data collected. This effect is dependent on the detailed approach to automation. The study team recommends that the FAA:

- Define how automated analysis of parameter data is applicable to remote certification.

- Define which parameters and sampling intervals are appropriate for failure anticipation.

Support for the certification decision is an example of processing that translates raw data from the remote facilities into decisions by the technician. Capability for failure anticipation depends on which, if any, parameters may have a gradually degrading mode of failure. The sampling interval for such parameters is then chosen to detect the trouble condition before it reaches a failure state. For example, in the case of lightwave transmission lines, error counts are obtained by an AT&T monitoring system (typically for a 15-second interval), multi-level thresholds are applied, and "soft alarm" reports are generated.

3.1.5 Minicomputer Hardware Specifications

The FAA plans to use minicomputers for a wide range of automated functions. In the case of RMMS, these functions are divided into two groups, known as MCS and the MMS. We recognize that the monitoring area is more limited in scope and thus more easily defined than the administrative area. MCS includes functions such as remote monitoring, certification, diagnostics, controls, adjustments, and failure anticipation. In the preceding section, we recommend modifications to MCS by standardizing the functional requirements and by defining the detailed approach to remote certification and failure anticipation. To determine the resulting effect on hardware specifications, we also recommend that the FAA:

- **Relate the sizing, selection, and location of MPS minicomputers to modified MCS requirements.**

The FAA should determine the number of minicomputers needed to handle input to the system (transaction rate and volume), functions within the system (software sizing), and database requirements. AT&T's experience with real-time, minicomputer-based systems has shown that the needed capacity often exceeds technical expectations

and that allowance should be made for about twice the estimated size.

The type of minicomputer hardware should be matched to the nature of its job. For example, MCS functions use a relatively static data base, (e.g., to identify remote facilities) whereas MMS functions require a more dynamic database (e.g., to update trouble history).

The location of minicomputers is also related to functional criteria. For example, MCS functions are more dependent than MMS functions on access to communications lines, which serve the remote facilities, and to maintenance personnel who support high availability of the minicomputer. In the AT&T environment, it is often possible to place a large number of minicomputers in the same room, so that the associated personnel and spare parts are also brought together.

3.2 SYSTEMS DEVELOPMENT

3.2.1 RMMS Distributed Processing

RMMS is a distributed processing system since the FAA has already allocated certain monitoring and control functions to the remote facilities and others to the central minicomputers. We now look at the area in between, where the question is how to transfer monitoring and control data in an accurate, efficient, and standard way. The answer is critical to the current feasibility of RMMS. The study team recommends that the FAA:

- **Use distributed processing to support the many-to-one transfer of monitoring and control data between remote facilities and a central minicomputer.**

This area includes I/O functions, interface functions, and their relation to data communications lines and protocols. Because of the FAA's existing need for basic RMMS capability, the study team assigns top priority to the above recommendation.

3.2.1.1 I/O Functions

As described in Section 2.3, the FAA is currently monitoring several remote facilities from an ARTCC in Olathe, Kansas. The central minicomputer is being used to perform a "polling" function which controls the data transfer. When polled for the purpose of alarm monitoring, a remote facility usually answers that no alarm condition exists. This request-and-response situation does not lead to action by the technician, but does occupy more of the central minicomputer's time as the number of monitored facilities increases. In the AT&T environment, we have found this to be an inefficient use of minicomputer resources. The study team, therefore, recommends that the FAA:

- Reduce the load on the central minicomputer by distributing the I/O functions, such as polling.

Such a distributed-processing approach relieves the minicomputer of data communications overhead. It also allows for the application of specialized hardware to functions which are I/O intensive.

3.2.1.2 Interface Functions

Once maintenance information from the remote facilities is transferred to the central minicomputer, it needs to be processed, stored, and displayed to the user. The kind of information processing performed in the central minicomputer depends on the functional content of messages received from the remote facilities. To reduce differences between the MCS packages to be developed for each facility type, Section 3.1.4.1 recommends that the FAA standardize for those RMSs which are yet to be defined in remote facilities. This does not, however, address the facilities in which embedded or retrofitted RMS is already defined. To lessen the need for facility modifications, the study team recommends that the FAA:

- Standardize the messages to and from the central minicomputer by distributing the interface functions.

The primary interface function is to translate some of the diverse content (e.g., parameter definitions) in messages sent or received by the remote facilities. There are also link-control procedures and message formats which do not meet the ICD and, therefore, need to be translated. Other important interface functions include data filtering (e.g., to extract the changed values from a set of parameter readings) and link concentration to combine messages from several remote facilities. For example, the study team was shown an FAA concentrator for the ILS which is already in use at a small airport outside Kansas City, Missouri. In the telecommunications environment, more than 10,000 AT&T interface units have been deployed to provide distributed processing. These AT&T units have also reduced the cost of new transmission equipment by off-loading functions such as adjustable thresholding and temporary storage.

3.2.1.3 Telemetry Concept

I/O functions and interface functions are closely related to the communications lines and message protocols which transfer the monitoring and control data (i.e., TCN, ICD). AT&T summarizes this whole concept by using the term "telemetry" (see Figure 3-3). Telemetry hardware lies in the area between remote facilities and a central minicomputer. Telemetry functions are distributed (i.e., processing occurs at both ends of a data communications line) and include polling, translating, filtering, and concentrating.

To illustrate the impact of these functions on data communications needs, consider the speed of information transfer. The required data rate can be reduced by filtering out unnecessary information; the number of data links to the central minicomputer can be reduced by concentrating data links from the remote facilities. Moreover, translating allows future facilities to be designed for lower-speed data links and simpler protocols. In this way, telemetry leads to lower communications costs.

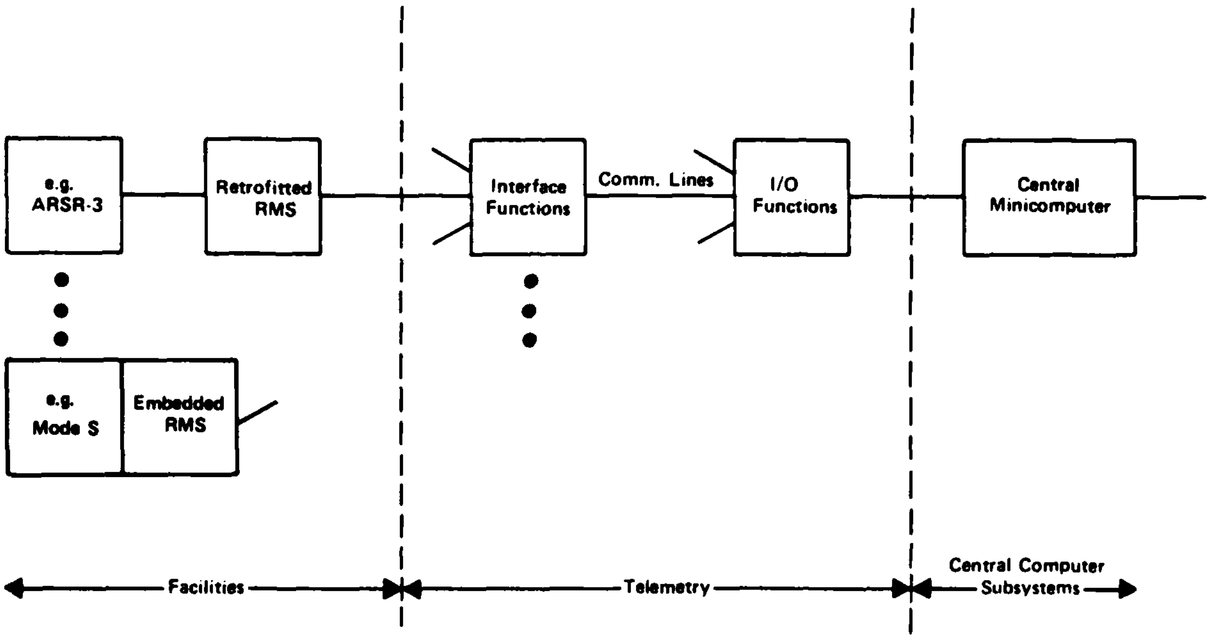

Figure 3-3. Telemetry Concept

3.2.2 Functional Systems Architecture

As described throughout this report, AT&T's approach to operations planning and systems design is to analyze the centralized maintenance jobs and to develop a functional systems architecture. This architecture then provides a road map for system requirements definition, for the development of new systems, and for the modification of existing systems. The result is a smooth transition to an automated environment that better supports the jobs of centralized maintenance. We recommend that the FAA:

- **Design an overall RMMS functional architecture that supports the maintenance organization.**

A functional architecture will guide the hardware and software decisions associated with the 80's Maintenance Program. Systems planning decisions will be based on the information derived from the allocation of functions to individual elements of the overall architecture.

An overall functional architecture, such as the one shown in Figure 3-4, is developed by allocating all the functions identified during sector planning to specific subunits of the system. When allocating these functions, the current environment, including systems deployed in the field, should be taken into account. New functions and architecture elements should be added as necessary based on cost evaluations. The architecture shown is divided into three areas: facilities, telemetry, and central computer subsystems.

The facilities are assigned the functions required for on-site maintenance and for remote monitoring and control of information. The telemetry subsystem is allocated the functions required to support facility surveillance. It provides for the efficient transfer and translation of the data necessary for monitor and control of the facilities. The facilities and telemetry functions were described in Section 3.2.1.

The central computer subsystems are assigned functions that automate the organization's administrative and operations functions. An important characteristic of this subsystem is flexibility.

Job functions and operations in maintenance organizations continue to evolve in unpredictable ways. These changes result from facility growth, technological change, and organization changes. For example, more processing power may be needed when new facilities are assigned to an organization. The need for increased processing requires the system to be flexible enough to accommodate this growth. New technology may require new interfaces and functions forcing the system to incorporate new types of facilities. Organizational changes, such as combining groups, reassignment of facilities, and control transfer during off hours, require the system to be flexible to accommodate these changes. The architecture shown addresses the flexibility issue in each element of the central computer subsystems.

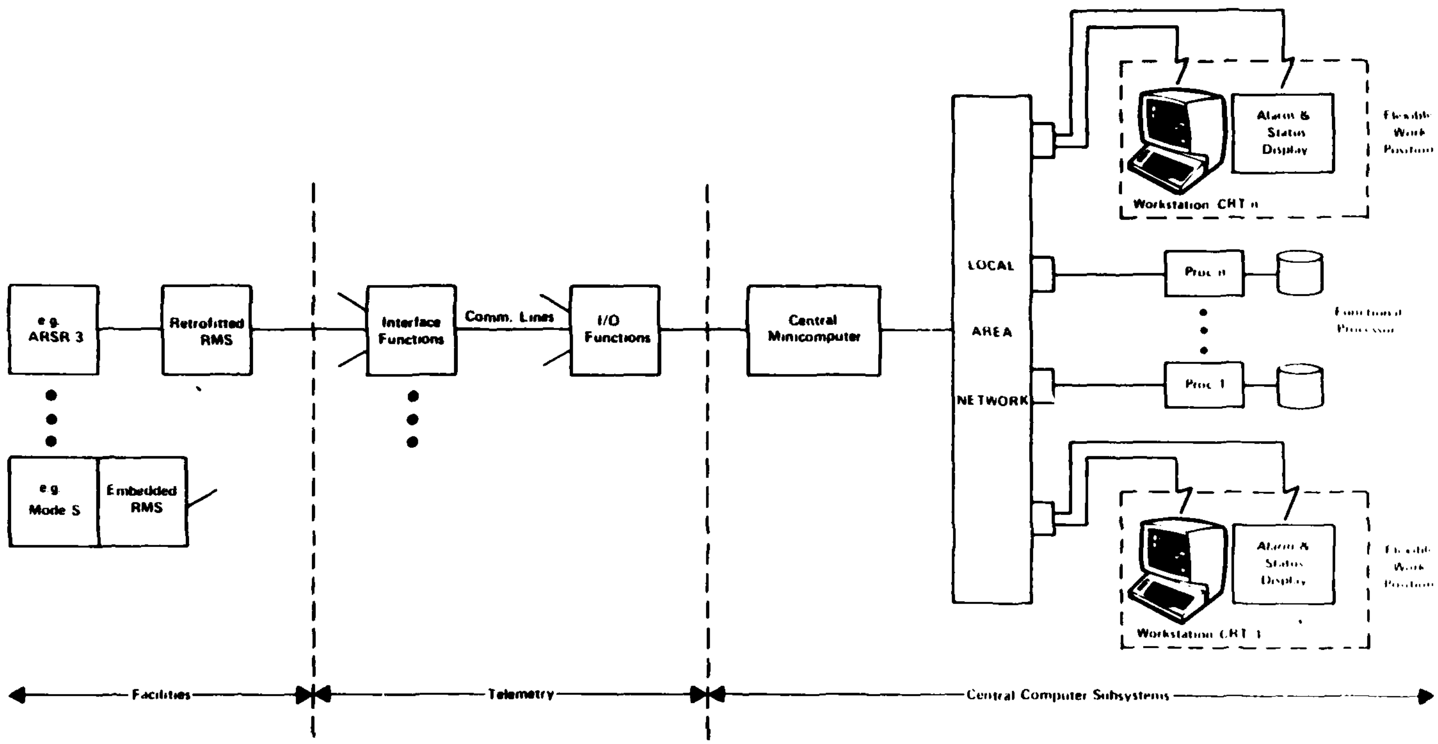

Figure 3-4. Example of RMMS Functional Architecture

Based on our related experience at AT&T, we suggest that certain functions be logically grouped together on functional processors. By developing different systems for different functions, there is an overall lower risk to the program. This benefit is derived from being able to deploy the most important function first, and the less critical ones later. This approach also prevents unanticipated problems associated with the development of one function from delaying the development of others.

Flexible work stations are allocated the person/machine interface functions. The work stations are designed to fit the individual needs of the jobs identified in Sector Planning. As the job functions change when centralization is introduced, new device requirements result, such as alarm and status displays. In a centralized environment, operations and associated work station needs will continue to evolve. Flexible work stations will allow individual positions to be adapted to meet the changing individual needs and allow easy deployment of new human interface devices and capabilities.

The final area of the example functional architecture depicted in Figure 3-4 is flexible communication arrangements. Our experience suggests that flexible communication arrangements are the key to the support of evolutionary changes. This flexibility will allow the system to accommodate work station reassignments, additional processors, or other needed hardware. It will also allow the system to accommodate operational changes. For example, flexible control of communications is needed for work station reassignment within a sector, and the ability to redirect data flows from one sector to another sector for off-hours transfer of coverage responsibility, i.e., fold-down. In this example architecture, the local area network would provide the necessary flexible communications capability to allow the organization to efficiently adapt to evolutionary change.

3.2.3 Sector Implementation

AT&T's overall modernization efforts have led to the development of many tools that facilitate implementation of centralized maintenance operations. This section presents a recommendation for a Model Sector Program, a detailed description of the Model Program and its relationship to the Standard Sector Configuration project, and, lastly, discussions of measurement plans, accountability changes, and training needs.

The FAA maintenance modernization program will establish centralized maintenance operations in the GNAS Sectors and reduce their number from 115 to 65. To achieve this goal, the existing sectors will be consolidated, sector boundaries will change, and new functions relating to RMM, training, spare parts, and repair will be handled in the sectors. New support systems will be introduced and new job positions will be created. In general, many aspects of the current sector structure and operation will change. The study team, therefore, recommends that the FAA:

- **Expand the planned Standard Sector Configuration into a Model Sector Program that includes implementing the model and defining new work functions resulting from centralization.**

3.2.3.1 Model Sector Program

One tool that was effective in the implementation of the AT&T centralized maintenance program was the Model Program. A Model Program involves four phases (see Figure 3-5) that begin with planning and end with full deployment of standard organizational structures, operations methods, and standard systems.

In the first phase, the sector plan and system designs are used to produce a detailed design for a representative work organization. This design includes, for example, job descriptions, sector interface specifications, and procedures for using the maintenance and administration systems. (The appendix details each of the elements of a model design.) This phase is crucial to the Model Program because it ensures that the elements of the design work together to support the tasks performed by people.

The next phase is to select one or two sectors and implement the model design. It is important to have a clear management commitment to the Model Program because it represents a new approach and carries risk. The model design should be carefully evaluated to determine if the expected benefits are being achieved. Measurements are important to this determination. The result of the evaluation should be used to change the model design, the work procedures, or the system design.

In the last phase, a Model Sector is established in each Region to be used as an example of an efficient AF Sector organization. It could be used to train other managers and guide them in establishing the design of the Model in their Sector.

The benefits of the Model Program are consistent operations and standard designs of maintenance and administration tools. AT&T found that model organizations lead to earlier realization of these benefits and a smoother transition into centralized operations.

The Standard Sector Configuration project is related to the first phase of the Model Sector Program. The project's product is to be a revised policy for Sector Configuration, documented in Order 1100.127B. The policy in this order has the objective of describing an efficient organization. The order sets standards for AF Sectors by defining the following:

- Sector mission
- Factors to be considered when configuring Sector boundaries and configuring Sectors
- Factors to be considered when determining Sector headquarters locations
- Subelements of the AF Sector
- Sector functional elements including Facilities Operations, Program Support, and Technical Support.

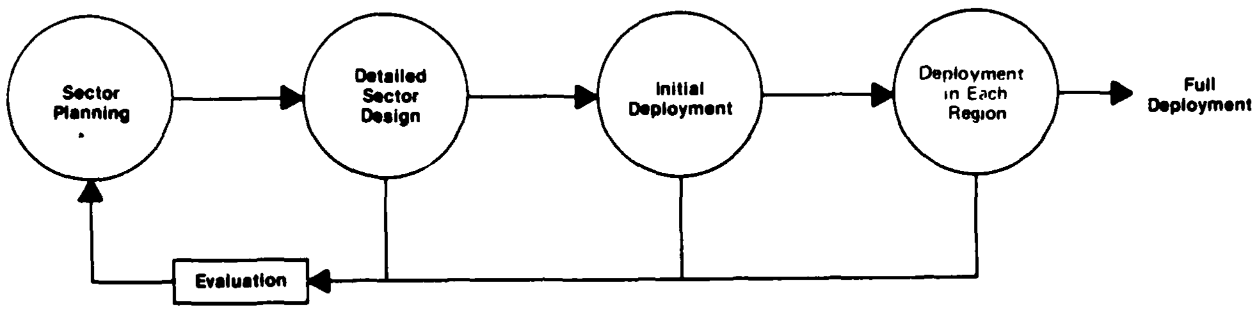

Figure 3-5. Phases of a Model Sector Program

To complete the work necessary for the first phase of the Model Program, the study team recommends that the FAA undertake the following additional work:

- Define detailed work procedures based on current work characterizations and on the impact of mechanized maintenance. In AT&T experience, these detailed work procedures are logical extensions of the work characterizations. The procedures are documented using a format similar to a flow-chart and are called Task Oriented Practices (TOPs).

- Define the relative roles and working procedures between AF sectors and interfacing organizations. In addition to understanding the relative roles of interfacing organizations, AT&T found that advance work is needed to prepare them for changes in the maintenance organizations. Providing information to interfacing organizations in advance smooths the transition and can prevent problems because work procedures have been modified to reflect new operational modes.

3.2.3.2 Measurement Plans

Another tool that was useful to AT&T was the implementation of a measurement plan for operational performance of maintained equipment (see the appendix). Measurements include outages, restoral times, customer complaints, and productivity. The restructuring of the GNAS Sectors will change operations, responsibilities, and jobs. In order to evaluate these changes, the study team recommends that the FAA also consider developing measurements plans. Current measurements focus on equipment outages and are important and should be continued. The study team recommends the following:

- Implement additional measures to allow further visibility into maintenance operations by looking at productivity, the effectiveness of interfaces with other organizations such as Air Traffic, and more specific service-affecting factors.

3.2.3.3 Accountability

Other effects of centralization are more directly related to maintenance personnel and their jobs. Currently, responsibility for a specific piece of equipment and its performance belongs to the technician who maintains that piece of equipment. In the remote maintenance environment, more than one technician may be involved in the detection, analysis, and repair of equipment failures. That means accountability will change. Because of this change, the study team recommends the following:

- Plan how the associated accountability of jobs should evolve as RMMS tools become available.

In our experience, we have found that technical and administrative tasks must change in order to operate efficiently in a centralized environment (see the appendix). Planning for these changes allow savings to be more readily realized. These plans are also useful in defining mechanized support tools to aid technicians. Equipment certification is an example of an area where this may become a major concern.

3.2.3.4 Training

The FAA is currently planning to offer training to technicians to facilitate the transition into an RMMS environment. In AT&T, training was also offered to managers because their tasks changed as centralized work forces were established. The need for management training was not initially apparent, but difficulties in establishing centralized operations pointed to its importance. The study team recommends the following:

- Develop training for sector management personnel in the area of implementation and administration of centralized maintenance operations.

The Sector Training project lists the provision of elective, management self-instruction courses as a planned activity. The study team recommends that the FAA consider the importance of this training and require that managers take formal courses. Also, we recommend that the content of the course focus on the area of implementation and administration of centralized maintenance operations.

3.3 SYSTEMS INTEGRATION

3.3.1 Program Management Function

There are FAA policy-level definitions of twenty-two systems integration and program control functions for the 80's Maintenance Program. They were assigned to various divisions before the last reorganization. More recently, the FAA has proposed that some of these functions be assigned to various AES, APM, and Regional organizations. The study team was unable to obtain a clear view of where the authority and responsibility for these functions lie at present.

We also found that there is little common membership or common middle management accountability in the several steering groups (e.g., RMMSG, LSSG) related to maintenance. Although each is attempting to find solutions to its particular problem areas, there is a need for overall coordination and control among the groups so that program oriented goals are achieved.

To ensure controlled implementation of the 80's Maintenance Program, we recommend the following:

- **Establish a Program Management function with the entire responsibility and authority for Maintenance Program planning and implementation.**

A Program Management function has the responsibility and authority for control of all Program elements. Figure 3-6 depicts the controlling role of this function with respect to the major planning and implementation activities described in Section 3.1. An approach is needed that functionally assures this control.

There are various ways of implementing such a function. For example, matrix management and direct in-line reporting are two established techniques. We do not endorse any one particular implementation. Rather, an approach is needed that will work effectively within the FAA environment. To be effective, the Program Management function must be perceived by all Program elements as being in control of the Program. The study team could not determine that such a view exists.

3.3.1.1 Sector Planning and Implementation

The responsibilities associated with the management of sector planning and implementation should parallel those functions recently proposed for APM-100. These would include, for example, sector planning, human relations issues, staffing levels, alternative implementation scenarios, and cost-effectiveness issues. The sector planning and implementation management responsibilities would also include ARTCC Sector planning.

3.3.1.2 System Planning and Implementation

The system planning and implementation management function needs to control all system elements required to implement the maintenance modernization program. This includes the RMM capabilities associated with all facilities (e.g., ASR-9, RMS, RCAG).

Specific areas where the system management function would be effective include the coordination of the different RMMS projects. Close coordination is also advisable because of the integral ties between software functional allocation and hardware selection, and because of the numerous individual projects dependent on a common architecture. For example, the MPS/RMMS hardware architecture needs to take into account the functionality which the MMS software tools may require. Likewise, the MMS software development process, which has placed reliability, maintainability, and availability constraints on the MPS hardware selection, must take into account the already existing RMMS architecture. Further, coordination among various facility projects is needed to ensure that management has appropriate guidance and that the RMM capabilities needed are, in fact, obtained.

The Program Management function should support the use of working groups (e.g., the RMMSG, the LSSG, and the LSSSG) as effective forums for both regional and headquarters roles in resolving technical issues. The relative roles and number of such groups, however, needs to be defined. The three current groups have overlapping responsibilities and charters. The role of a single steering group, for example, could be defined to include the following additional functions:

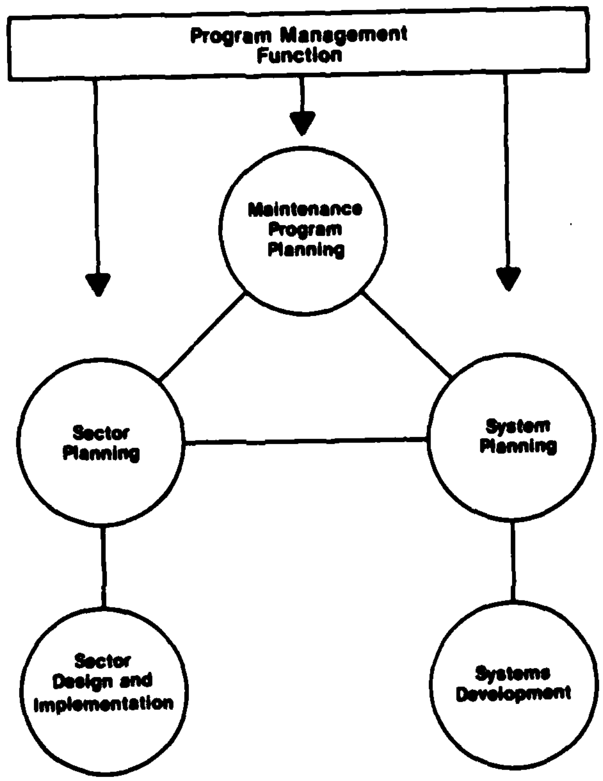

Figure 3-6. Program Management Function

1. Provide a forum for all elements of the maintenance program, including maintenance (MCS) and administrative (MMS) programs.

2. Monitor closely all telecommunications networking activity needed for the RMMS Program.

3. Assist in the coordination of all activities at the working level for RMMS and RMM capabilities. Specifically, all proposals for RMM capabilities in facility projects should be reviewed.

Alternatively, the charters of the RMMSG, the LSSG, and the LSSSG could be redefined and clarified to allow joint performance of these functions.

3.3.2 Relationship Among RMMS Contractors

We considered the need to define an integrated structure for relationships among contractors for RMMS, contractors for facilities, the Systems Engineering and Integration (SEI) contractor, and the FAA. This section identifies potential roles of FAA and its contractors in carrying out the functions shown in the structured planning and implementation concept in Figure 3-1.

There are three areas which should be recognized in defining these relationships.

- Mission needs (e.g., functional availability to support the pilot and the controller).

- Maintenance operations needs (e.g., alternative sector configurations, systems functions needed to support sectors, facility features needed for maintenance).

- Technical and engineering needs (e.g., technical interfaces between maintenance systems and maintained facilities, protocols, deployment schedules).

Authority in all of these areas is vested in the FAA, with certain responsibilities delegated to contractors. In Section 3.1 we defined the planning concept for the Program which is shown in Figure 3-1. This same concept could serve as the basis for defining the relationship among contractors. This relationship is shown in Figure 3-7.

The SEI contractor will help the FAA manage the NAS Plan implementation. The SEI contractor has the responsibility for ensuring consistent technical requirements across numerous projects, and for technical interface specification and control. Consistent maintenance operations requirements on the facility projects (e.g., alarm messages and thresholds) are provided by the FAA to the SEI contractor based on analyses of mission functional availability needs and on plans for how Airway Facility personnel will meet these needs. Since the SEI contractor's responsibilities include only technical requirements, their role is bounded as indicated in Figure 3-7.

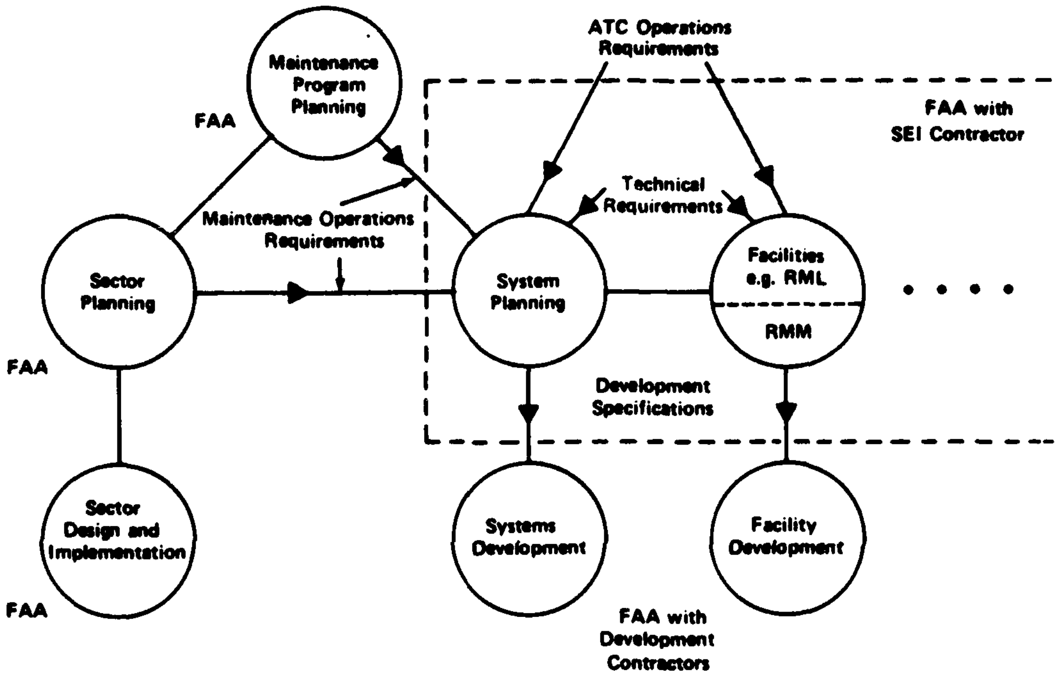

Figure 3-7. Potential Relationships Among FAA and Contractors for the 80's Maintenance Program

Systems development is normally undertaken within the FAA (e.g., at the Technical Center) and by contractors. The SEI contractor will ensure that technical interface requirements are met and that testing and installation proceed as specified.

The remaining systems engineering functions (see Figure 3-7) are FAA responsibilities and include maintenance program planning, sector planning, and sector design. Typical work which the FAA needs to accomplish in these areas is as follows:

- Implement and adhere to a structured planning process based on a proven low-risk model which integrates the human and logistic elements, e.g., operations planning.
- Plan detailed sector maintenance functions, including the lead sector program and its evolution, and integrate this work with system planning.
- Design model sectors and guide their implementation in the field.

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